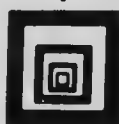


**CIHM
Microfiche
Series
(Monographs)**

**ICMH
Collection de
microfiches
(monographies)**



Canadian Institute for Historical Microreproductions / Institut canadien de microreproductions historiques

© 1999

The copy filmed here has been reproduced thanks to the generosity of:

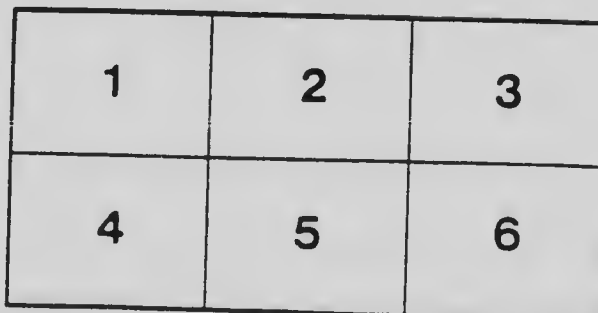
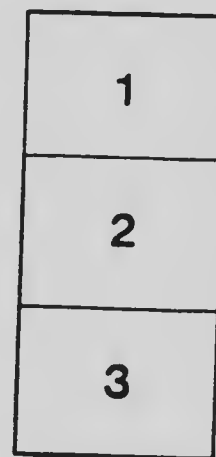
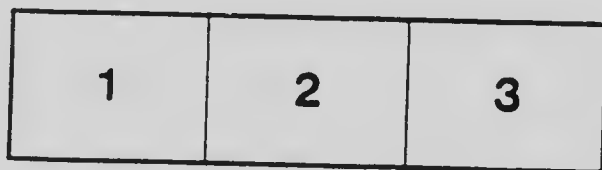
National Library of Canada

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol \rightarrow (meaning "CONTINUED"), or the symbol ∇ (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:



L'exemplaire filmé fut reproduit grâce à la générosité de:

Bibliothèque nationale du Canada

Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'original filmé, et en conformité avec les conditions du contrat de filmage.

Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole \rightarrow signifie "A SUIVRE", le symbole ∇ signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bas, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.

MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No. 2



APPLIED IMAGE Inc.

200 North Main Street
Rochester, NY 14609
Tel: (716) 462-1000

7.11.51

RECEIVED
17-11-1981

UNIVERSITY OF TORONTO
LIBRARY

PUBLICATIONS
OF THE
Dominion Astrophysical Observatory
VICTORIA
Vol. 1, No. 4.

ORBIT OF THE SPECTROSCOPIC BINARY ϵ GEMINORUM

BY REYNOLD K. YOUNG

Y

ϵ Geminorum [α (1900) = $5^h 58^m 0.0$, δ + $23^\circ 16'$, vis. mag. = 4.30, type G5.] was announced as a spectroscopic binary in Lick Obs. Bul. Vol. IV, page 107. Four spectrograms were made at the Lick Observatory from 1903 to 1906. Three additional spectrograms were made at the Bonn Observatory from 1909 to 1912. The star was placed on the observing list at Ottawa in December of 1916 in the hope that the range might prove large enough to permit its orbit being obtained with one prism dispersion. Twenty-six plates were secured in the early months of 1917 but these did not seem sufficient to give accurate elements and it was therefore left to be finished from observations with the 72-inch reflector at Victoria.

The determination of the period has proved to be difficult. Fifty-one observations have been secured here and these are in harmony with a period of 9.590 days. This same period will satisfy the Ottawa observations in 1917 very well and the Bonn observations in 1909 and 1912. The residuals are somewhat larger than one would be led to expect from the fine quality of the spectrum but on the whole they indicate that the period 9.590 days is satisfactory. The Lick observations taken in 1903 to 1906 could not be made to agree and it would seem that there are peculiarities in the orbit not yet explained. The double amplitude of the curve is twenty-three kilometers only and the irregularities in the curve are of the order of five kilometers or a little over so that the complete investigation with one prism dispersion would prove a difficult task. Three prism dispersions would be much better but until such is available the present elements serve as a good approximation to give the general form of the curve.

In the table of observations, which follows, the plates taken at Ottawa were measured with the Toepfer measuring machine while the Victoria spectrograms were measured on the Hartmann comparator with a sky or a Bootis standard. Some of the plates were measured with both standards and seemed to give practically the same result.

TABLE OF OBSERVATIONS

Plate	Observer	Date	Julian Day	Velocity	Wt	Phase	O.C.
Lack		1903 Jan 4	2,116,419.78	+33.8		0.52	
"		1905 Sept 27	7,116.01	+19.8		1.83	
"		1906 Oct 1	7,185.01	+15.8		6.41	
"		" Nov 9	7,521.98	+19.9		8.02	
Bonn		1909 Jan 22	8,329.43	+12.3		6.91	-0.9
"		" 25	8,332.42	+16.9		0.41	-0.7
"		1912 Feb 7	9,110.38	+21.2		5.12	-1.7
Ottawa							
7950	Y	1916 Dec 17	2,121,215.621	+19.6	1	6.51	+3.4
7989	"	1917 Jan 12	1,211.632	+35.0	1	3.75	+6.1
7998	"	" 16	1,215.683	+7.5	1	7.80	+0.3
8013	"	" 22	1,251.771	+35.6	1	1.30	+8.3
8014	"	" 26	1,255.169	+12.7	1	8.00	+6.5
8027	"	Feb 1	1,261.758	+29.0	1	1.70	+3.0
8044	"	" 11	1,271.658	+26.1	1	5.01	+1.1
8045	"	" 14	1,271.708	+27.0	1	5.06	+2.2
8049	"	" 12	1,272.619	+16.1	1	5.97	-3.9
8052	"	" 12	1,272.676	+17.5	1	6.03	-2.0
8061	"	" 15	1,275.762	+15.1	1	9.11	+6.1
8063	"	" 18	1,278.581	+26.9	1	2.34	-1.7
8064	"	" 18	1,278.658	+37.7	1	2.42	+9.0
8071	P	" 21	1,281.517	+5.3	1	8.28	-0.5
8073	Y	" 27	1,287.507	+28.9	1	1.68	+2.3
8082	"	Mar 1	1,289.556	+33.8	1	3.73	+5.2
8098	"	" 6	1,291.562	+9.0	1	8.73	+2.2
8099	"	" 6	1,291.619	+10.4	1	8.79	+1.1
8100	"	" 6	1,291.674	+8.5	1	8.84	+0.8
8110	"	" 13	1,301.508	+14.4	1	6.09	-5.2
8111	"	" 13	1,301.564	+14.6	1	6.14	-1.2
8112	"	" 15	1,303.528	+5.0	1	8.11	-1.0
8116	C	" 16	1,304.644	+16.4	1	9.22	+6.4
8138	Y	April 8	1,327.528	+29.3	1	3.31	+0.2
8144	"	" 10	1,329.526	+18.9	1	5.34	-1.7
8142	"	" 10	1,329.580	+16.6	1	5.39	-6.1
Victoria							
778	Y	1918 Oct 28	2,121,895.967	+23.5	1	5.97	+3.5
823	"	" 30	1,897.929	+7.7	1	7.93	+1.1
856	"	Nov 1	1,902.937	+29.1	1	3.35	+0.3
900	"	" 20	1,918.891	+13.5	1	0.12	-1.5
901	"	" 20	1,918.904	+10.9	1	0.13	-1.1
926	"	" 22	1,920.937	+20.9	1	2.47	+2.7
927	"	" 22	1,920.951	+30.1	1	2.18	+2.2
988	P	" 26	1,921.902	+21.7	1	6.13	+2.9
1024	Y	Dec 10	1,938.912	+23.9	1	0.96	+1.5
1040	"	" 11	1,942.925	+28.9	1	1.97	+3.8
1068	"	" 16	1,944.816	+10.6	1	6.90	-2.7
1098	"	" 20	1,948.822	+25.7	1	1.28	+1.1
1099	"	" 20	1,948.828	+21.7	1	1.29	+0.1
1118	P	" 29	1,957.834	+20.2	1	0.70	-0.1
1119	"	" 29	1,957.843	+19.3	1	0.71	-1.2
1186	"	" 31	1,959.785		0	

TABLE OF OBSERVATIONS—Continued

Plate	Observer	Date	Julian Day	Velocity	W.C.	Phase	O.C.
1203	Y	1919 Jan 6	2,121.965-822	+4.0	1	8.69	-2.5
1204	"	" " 6	1,965.829	+5.4	1	8.70	-1.1
1270	"	" " 10	1,969.803	+27.2	1	3.08	-2.0
1271	"	" " 10	1,969.811	+30.0	1	3.09	+0.8
1272	"	" " 10	1,969.819	+26.1	1	3.10	-3.1
1295	P	" " 19	1,978.782	+26.1	1	2.17	-2.3
1306	Y	" " 29	1,988.719	+26.6	1	2.82	-2.5
1307	"	" " 29	1,988.728	+25.8	1	2.83	-3.3
1327	P	" " 30	1,989.787	+25.2	1	3.89	-3.1
1328	"	" " 30	1,989.795	+21.6	1	1.90	-3.7
1342	Y	" " 31	1,990.744	+27.1	1	4.81	+1.8
1343	"	" " 31	1,990.749	+27.9	1	4.85	+2.3
1360	P	" Feb 1	1,991.834	+21.1	1	5.93	+0.9
1381	"	" " 2	1,992.714	+12.3	1	6.81	-1.7
1382	"	" " 2	1,992.719	+12.8	1	6.82	-1.2
1391	"	" " 4	1,994.723	+9.2	1	8.82	+2.1
1395	Y	" " 5	1,995.584	+13.3	1	0.09	-1.3
1396	"	" " 5	1,995.592	+10.3	1	0.10	-1.3
1397	"	" " 5	1,995.601	+12.0	1	0.11	-2.7
1407	"	" " 5	1,995.800	+13.7	1	0.31	-3.1
1408	"	" " 5	1,995.811	+12.9	1	0.32	-3.9
1409	"	" " 5	1,995.820	+13.3	1	0.33	-3.5
1427	"	" " 11	2,001.772	+17.1	1	6.28	-0.5
1428	"	" " 11	2,001.778	+17.4	1	6.29	-0.5
1448	P	" " 16	2,006.735	+25.0	1	1.66	-1.5
1449	"	" " 16	2,006.742	+26.5	1	1.66	0.0
1477	"	" " 21	2,011.695	+14.4	1	6.61	-1.0
1491	"	" " 23	2,013.749	+9.5	1	8.67	+3.0
1492	"	" " 23	2,013.756	+9.7	1	8.68	+3.2
1516	"	" Mar 8	2,026.651	+28.2	1	2.39	-0.5
1559	Y	" " 19	2,037.626	+25.4	1	3.78	-2.8
1583	P	" " 20	2,038.675	+26.8	1	4.82	+1.2
1603	Y	" " 21	2,039.638	+23.3	1	5.79	+2.3
1642	P	" " 23	2,041.722	+6.2	1	7.87	-0.5
1643	"	" " 23	2,041.727	+7.8	1	7.88	+1.0
1662	Y	" " 24	2,042.625	+2.1	1	8.77	-1.7

Both the Ottawa and Victoria measures were used in forming the following normal places.

	Phase from J. D. 2,121,800	Velocity	W.C.	Preliminary O.C.	Final O.C.	Preliminary p.v.v.	Final p.v.v.
1	9.468	+12.3	1.33	-0.60	-0.12	.48	.01
2	0.790	+21.4	0.50	-0.05	.00	.00	.00
3	1.472	+25.5	0.67	-0.06	-.09	.00	.01
4	2.317	+26.8	1.69	+1.34	+1.26	1.30	1.59
5	3.163	+28.3	1.16	1.31	+0.89	2.00	.92
6	3.884	+27.1	0.84	-1.63	-0.99	2.22	.84
7	4.980	+25.9	1.00	0.00	+0.86	.00	.71
8	6.037	+20.1	1.00	-0.20	-0.91	.01	.88
9	6.393	+16.4	0.50	-1.30	-0.68	.85	.23
10	6.843	+14.9	0.50	-2.32	-1.88	2.69	1.76
11	7.968	+7.3	0.67	+0.60	+0.83	.21	.46
12	8.722	+6.5	1.50	-0.66	-0.41	.66	.00

00925710

From these normal places the preliminary elements were determined graphically.

$$\begin{aligned} P &= 9.590 \text{ days} \\ T &= \text{J. D. } 2,121,898.559 \\ e &= 0.20 \\ \omega &= 195 \\ K &= 11.75 \text{ km.} \\ \gamma &= 420.13 \text{ km.} \\ c &= -17.85 \text{ km.} \end{aligned}$$

The residuals which the normal places leave when represented by the elements are shown under the heading O. C. preliminary in the table of normal places. Observation equations were formed for these residuals and the elements adjusted by the method of least squares. The steps in the solution are recorded below.

OBSERVATION EQUATIONS

							Wt
1	1.000x	615y	+ 577z	959u	+1.151v	600 = 0	1.33
2	1.000	087	+1.050	1.012	952	- 050	0.50
3	1.000	162	+ 388	808	631	-060	0.67
4	1.000	726	498	416	280	+1.110	1.00
5	1.000	807	962	059	005	1.310	1.16
6	1.000	738	935	259	199	1.630	0.83
7	1.000	191	232	678	503	0.000	1.00
8	1.000	006	+ 781	928	813	+0.200	1.00
9	1.000	-207	+1.004	918	904	-1.300	0.50
10	1.000	503	+1.025	899	972	-2.320	0.50
11	1.000	1.113	578	262	128	+ 600	0.67
12	1.000	-1.101	812	+ 161	590	- 660	1.50

$$\begin{aligned} \text{where } x &= d\gamma \\ y &= dK \\ z &= Kdr \\ u &= Kd\omega \\ v &= \frac{-K\mu}{(1-e^2)^2} dT \end{aligned}$$

NORMAL EQUATIONS

$$\begin{aligned} 10.667x & & 416y & & -896z & & + 611u & & + 902v & & - 1.811 = 0 \\ & & +5.501 & & - 851 & & - 861 & & - 1.193 & & + .392 = 0 \\ & & & & + 6.031 & & - 583 & & - .173 & & + .555 = 0 \\ & & & & & & + 1.978 & & + 4.903 & & + .855 = 0 \\ & & & & & & & & + 5.015 & & + .107 = 0 \end{aligned}$$

$$\begin{aligned} \text{whence } x &= -0.1161 & \text{or } d\gamma &= -0.42 \text{ km.} \\ y &= -0.0082 & dK &= -0.01 \text{ km.} \\ z &= +0.0762 & de &= +.0065 \\ u &= +1.6985 & d\omega &= +8.28 \\ v &= -1.1903 & dT &= +0.182 \text{ day.} \end{aligned}$$

The final elements are

$$P = 9.590 \text{ days}$$

$$e = 0.2065 \quad \cdot 0344$$

$$K = 11.74 \text{ km.} \quad \cdot 33 \text{ km.}$$

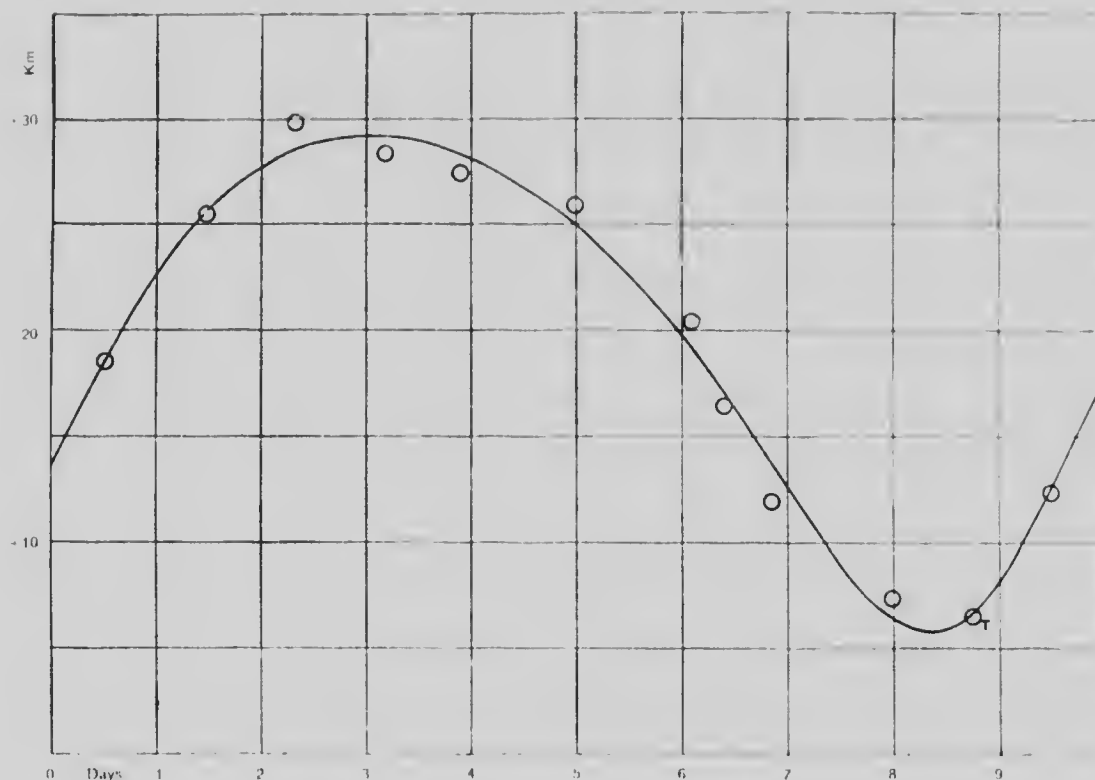
$$\gamma = +19.71 \text{ km.} \quad \cdot 22 \text{ km.}$$

$$\omega = 203.28 \quad \cdot 6780$$

$$T = \text{J. D. } 2,421,898.741 \quad \cdot 196 \text{ day}$$

$$a \sin i = 1,510,000 \text{ km.}$$

$$\frac{m_1 \sin^3 i}{(m_1 + m_2)^2} = -0.015$$



These elements are suggestive of the spectroscopic elements for the cepheid variables. The period is the shortest yet found for a star of G type if we exclude the Cepheids but is quite normal for a star of that class. The range is small and the eccentricity high for a binary of such short period. The orbit is minute. The observations do not fit the curve as well as the character of the spectrum would lead one to expect, the probable error of a single plate being, for Victoria, 4.61 km., for Ottawa, 3.00 km. All these characteristics belong also to the Cepheids. On the other hand the star has not been observed to vary and accepting Adams' value for the parallax and luminosity, $\pi = 0.052$, $L = 6.92$ the absolute magnitude is $+2.82$. According to Shapley's curve in the *Astronomical Society of the Pacific*, February, 1918, for the Cepheid variables, a star of this period and apparent

magnitude should have an absolute magnitude of -3.0 . The writer suspected the spectrum to vary somewhat from F8 to G5 or K, but on making estimates of the relative intensities of the pairs of lines used by the Mount Wilson Observatory for the determination of type, this apparent variation vanished and it was further noticed that the altered appearance of the spectrum depended on the exposure of the plates. Those plates that were normal were all alike but the over-exposed plates, of which there were several, had the absorption lines so veiled over as to make the spectrum at first glance resemble an earlier type than it really was.

The tentative conclusion one would be led back to is that the star is probably not a cepheid variable but that it is a G type binary with the shortest period yet found and that the discrepancies in the earlier observations render it advisable to investigate the star further when higher dispersion is available.

Dominion Astrophysical Observatory,

Victoria, B.C.

July, 1919.

